

Genetic Algorithm based Optimal Placement of Distributed Generation Reducing Loss and Improving Voltage Sag Performance

Soma Biswas¹ and S.K. Goswami²

¹ Department of Electrical Engineering, J.I.S. College of Engineering, Kalyani, West Bengal, India
Email: somsun_tara@yahoo.com

² Name Department of Electrical Engineering, Jadavpur University, Kolkata, West Bengal, India
Email: skgoswami_ju@yahoo.co.in

Abstract—This paper proposes a genetic algorithm optimization technique for optimal placement of distributed generation in a radial distribution system to minimize the total power loss and to improve the voltage sag performance. Load flow algorithm and three phase short circuit analysis are combined appropriately with GA, till access to acceptable results of this operation. The suggested method is programmed under MATLAB software. The implementation of the algorithm is illustrated on a 34-node radial distribution system. Placement of two DGs with fixed capacity has been considered for example. Only the three phase symmetrical faults are considered for sag analysis though other fault types are more common.

Index Terms—Distributed Generation, Line Loss, Voltage Sag, Genetic Algorithm, and Radial Distribution network

I. INTRODUCTION

Distributed generations (DG) [1] are connected at the low or medium voltage parts of power system. Among the objectives that are considered as primary goals while determining the DG size and sites are the minimization of transmission loss, maximization of supply reliability, maximization of profit of the distribution companies (DISCOs), etc have found wide acceptance [2-3]. There have been many studies, to define the optimum location of distributed generation. Fuzzy approach and Genetic Algorithm (GA) are used to find the optimal locations and sizes of DG units in [4-5].

The problem may seem to be a DG placement problem but one may call it as power quality (PQ) problem also as this reduces the voltage sag problem which is probably most important power quality problem. Voltage sag magnitudes are closely related with the short circuit level of the network [6]. As fault level at distribution systems were rather low, voltage sag is a major problem in distribution system. DG connections increase the short circuit level, thus tending to reduce the voltage sag problem. It is thus imperative that manipulating the site of DG connection may be an effective way to reduce voltage sag problem.

The present paper, while attempting a solution in this direction, formulates the DG placement problem as a multi-objectives optimization problem consisting of power loss and voltage sag as the objectives to minimize. The multi-objective optimization problem is solved using genetic algorithm. The reason for selecting GA is that the problem is

combinatorial in nature and GA is perhaps the mostly used general purpose optimization technique to solve such problems.

II. COMPUTATION OF SAG

Several indices have been developed in literature to measure the impact of sag. These indices are not suitable for direct use in the DG placement problem. Number of customers affected due to the voltage sag may be a probable measure, but it is felt that KVA/MVA capacity of the loads disturbed due to sag would be a better indicator of the severity of the voltage sag as it would include both the number of customers and the effected loads.

The present paper attempts to solve the voltage sag magnitudes under fault condition performing simple short circuit analysis. The pre-fault voltages at different buses are considered to be 1 p.u. and loads are presented by their equivalent impedances. The fault impedance is assumed to be very less in the order of 10^{-6} p.u. Performing short circuit analysis the voltages are observed and those buses are identified which has voltage less than V_{TH} . Where V_{TH} (0.85 pu here) is the threshold voltage below which the loads are disturbed due to voltage sag problem. Then the loads connected at those buses are added to get total load disturbed for that particular fault. This method is repeated for all the possible faults. For different DG locations the fault places are kept fixed.

Thus the total load disturbance for every location of DG presented in KVA or MVA will be considered as a measure of sag performance. For two DG also the same method is applied. In that case the system with a single DG is considered to be the base system.

III. PROBLEM FORMULATION

A. The objective function

The function that has to be minimized consists of two objectives:

- Minimize the active power losses:

Mathematically, the objective function can be written as:

$$\text{Minimize } P_L = \sum_{k=1}^{N_{SC}} Loss_K \quad \text{----- (1)}$$

K-different section
N_{SC}- number of section

- Minimize the load disturbed S_{DIST}

$$S_{DIST} = \sum_{i=1}^{N_F} LoadDist_i \quad \text{----- (2)}$$

N_F is the number of faults; LoadDist is the load disturbed due to one fault.

B. Operational constraints:

- **Power flow balance equations:** The balance of active and reactive powers must be satisfied in each node:
- **Power flow limit:** The apparent power that is transmitted through a branch *l* must not exceed a limit value, S_{lmax}, which represents the thermal limit of the line or transformer in steady state operation:

$$S_l \leq S_{lmax} \quad \text{----- (3)}$$

- **Bus voltages:** For several reasons (stability, power quality, etc), the bus voltages must be maintained around the nominal value:

$$U_{i min} \leq U_i \leq U_{i max} \quad \text{----- (4)}$$

IV. PROBLEM MODELLING WITH GA

Generally, GA comprises three different phases of search: Phase1: creating an initial population; phase 2: evaluating a fitness function; phase -3: producing a new population. GA optimizes a single variable, the fitness function. Hence, the objective function and some of the constraints of the problem at hand must be transformed into some measure of fitness.

Encodings: The design of chromosome is very simple in this problem. As only the location is to determine thus location of DG₁ and location of DG₂ from the two component vector as shown in figure-1.

DG ₁	DG ₂
Position (bus number)	Position (bus number)

Figure 1: Chromosome encoding for Two DG unit

Both the components can take values from 2 to N. Two DG always are placed in different location other than slack bus.

Fitness Function: This function measures the quality of chromosomes and it is closely related to the objective function. Objective function for this paper is computed from equation (1) and (2). The effect of constraints is included in the fitness function by checking separately and the violations are handled using a penalty function approach. The overall fitness function designed during the study is

$$f(x) = \frac{P_L}{P_{Loss}} + \frac{S_{DIST}}{S_{Bdist}} - \xi \sum_{i=1}^{nr} bal_i - \zeta \sum_{k=1}^n thermal_k - \mu \sum_{k=1}^n voltage_k \quad \text{----- (5)}$$

where the first two terms are the objective function and the penalty functions, respectively. The last three sums are a measure of unfeasibility for each candidate solution. The penalty factors (ξ, ζ, and μ) used in this study was set to 1000. The elements *bal_i*, *thermal_k* and *voltage_k* are equal to 0 if the constraints are satisfied, 1 otherwise.

The complete MATLAB program consisting load flow algorithm, short circuit analysis and Genetic Algorithm for solving the DG placement problem can be written in the simplified form as below:

```

BEGIN
Read network data
Run Newton Raphson load flow and store results for base case
Run short circuit analysis without DG to get the base case result
Encode network data
Set genetic parameters
Create initial population
While < stopping condition not met > execute
For each individual in current generation
Run power flow
Run short circuit analysis
Evaluate fitness
End For
Select (current_generation, population_size)
Crossover (selected_parents, crossover_rate)
Mutation ( current_generation, mutation_rate)
Current_generation++
Endwhile
Show solution
End

```

Roulette Wheel Selection, which chooses parents by simulating a roulette wheel with different sized slots, proportional to the individual's fitness, is chosen here. The one point and scattered crossover mechanisms were tested in this study. The crossover rate was set to 0.85. The mutation rate was set to 0.2. Initial population in this paper was generated randomly, with individuals within the bounds set for each independent variable of the problem.

V. IMPLEMENTATION AND RESULTS

The proposed method is applied to a 34-bus, 11 KV radial feeder with lateral branches (figure-2). The details of the network and the load characteristics are provided in [7].

The total installed peak power demand of the system is 5.4MVA, with an average power factor of 0.85. The system has a power loss of 222 KW and minimum system voltage 0.947 pu observed at bus 27.

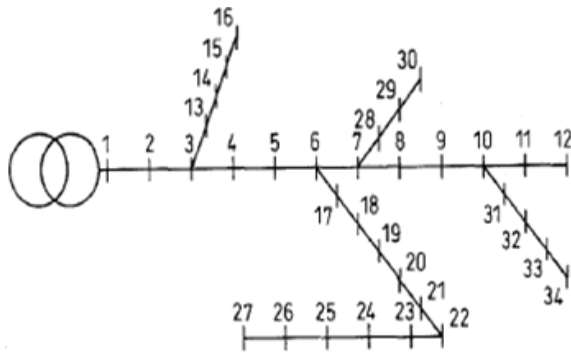


Figure 2. Single line diagram of a 34 bus radial system.

In this problem two DGs of capacity 1.5 MW and 0.4 MVAR are considered to be installed.

TABLE-I:
COMPUTATIONAL RESULTS WITH THE GENETIC ALGORITHM APPROACH

No of DG units	Losses [KW]	Load disturbed [MVA]	Solution		
			location		size
Without DG	222	169.462	NA	NA	NA
1	116.6	74	19	NA	fixed
2	45.5	46	24	7	fixed

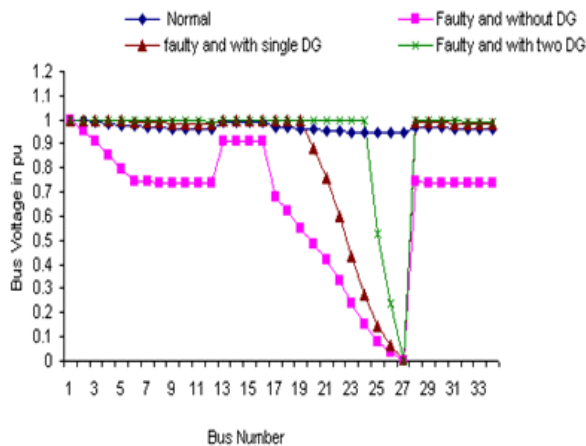


Figure-3: Bus voltages at four different cases.

RESULTS

The GA was run 100 independent times, starting from a different initial population at each simulation. Different solutions were obtained at each run, as the initial population, which gives the first genetic material, is randomly generated. Furthermore, the entire algorithm is based on random processes. Nevertheless, because of the high ratio of similar results indicating bus number 24 and 7 as best locations, one can accept this result as accurate.

Table-I shows that under normal condition total active power loss is 222kw and load disturbed due all possible faults is 169.462 MVA.

Table-I shows how the loss and load disturbed value get reduce due to the introduction of DG's. It can also be concluded that how the number of DG affects on loss and sag performance.

In figure-3 a clear comparison is made among the voltage profile under four different cases. Case1: Under normal condition, Case-2: Under fault without any DG unit, case-3: Under fault with one DG unit, Case-4: Under fault with two DG unit.

VI.CONCLUSIONS

This paper presented a new formulation of the DG placement problem using genetic algorithm. As the authors' intention was to highlight on the necessity of incorporating the voltage sag as an objective of the optimization problem, the implementation was based on some simplified assumptions as consideration of three phase faults only or the fault locations being the system buses, etc. These limitations, however, can be overcome very easily. Currently the authors are working on these issues.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Management of JIS College of Engineering, Kalyani and the Management of Jadavpur University, Kolkata, INDIA for their continued support, encouragement and the facilities provided to carry out this research work.

REFERENCES

- [1] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans, W. D'haeseleer, 2005. "Distributed Generation: Definition, Benefits and Issues". *Energy Policy*, 33: 787-798.
- [2] W.El-Khattam, K.Bhattacharya, Y.Hegazy, M.M.A. Salama, "Optimal Investment Planning for Distributed Generation in a Competitive Market," *IEEE Transactions on Power Systems*, Vol.19, No. 3, August 2004, pp 1674-1684.
- [3] [2] G. P. Harrison, A. Piccolo, P. Siano, A. R. Wallace, "Exploring the Tradeoffs Between Incentives for Distributed Generation Developers and DNOs," *IEEE Transactions on Power Systems*, Vol. 22, No.2, pp. 821 -828, May 2007.
- [4] Ramalingaiah Varikuti, Dr. M.Damodar Reddy, "Optimal Placement of DG Units Using Fuzzy and Real Coded Genetic Algorithm," *Journal of Theoretical and Applied Information Technology* 2005 -2009, pp.145-151.
- [5] K.H. Kim, Y.J. Lee, S.B. Rhee, S.K. Lee, S.-K. You, Dispersed Generator Placement Using Fuzzy-GA in Distribution Systems. *IEEE PES Summer Meeting*, 2002, 3: 1148-1153.
- [6] Math H. J. Bollen, Mats Hager, "Impact of Increasing Penetration of Disturbed Generation on the Number of Voltage Dips Experienced by End-Customers," *18th International Conference on Electricity Distribution*, Turin, 6-9 June, 2005.
- [7] M. Chis, M. M. A. Salama, S. Jayaram, "Capacitor Placement in Distribution Systems Using Heuristic Search Strategies," *IEE Proceedings, Generation Transmission Distribution vol.144, no.3*, May- 1997.